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ALBERTA DEPARTMENT OF AGRICULTURE
WATER RESOURCES DIVISION
SOILS, GEOLOGY AND GROUNDWATER BRANCH

IRRIGATION STUDY BASIN
Annual Report No. 1
Calendar Year 1967

Prepared By Co-operating Agencies

Edited & Prepared By

Grant L. Nielsen

Hydrogeologist

EDMONTON, ALBERTA

March, 1968

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ALBERTA DEPARTMENT OF AGRICULTURE
Water Resources Division
Soils, Geology and Groundwater Branch

First Annual Report

Irrigation Study Basin, 1967

I.H.D. Project

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Prepared by:

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March, 1968

First Annual Report

Irrigation Study Basin, Alberta

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Irrigation Study Basin - First Annual Report on Activities of 1967

INTRODUCTION

The world-wide growth of population and industrialization have led to an increasing concern for adequate water supplies in recent years. One result of this has been the declaration of an "International Hydrologic Decade" under United Nations auspices from 1965 to 1974. During this time, scientists of all nations are focusing their attention on water: measurement, management, pollution control, and many other aspects.

One such project of considerable interest in Canada is the "Irrigation Study Basin" in Southern Alberta, national I.H.D. project IWB-EB-14, Alberta project 71. This is the first study of this scope ever attempted in Canada on an irrigated basin.

LOCATION, ACCESSIBILITY AND CLIMATE

The "Irrigation Study Basin" is a portion of the Oldman River drainage in Southern Alberta, Canada. It lies approximately between latitude 49° 30'N and 49° 50'N and longitude 112° 20'W and 112° 50'W. The area is approximately 396 square miles or 990 square kilometers. Elevation ranges from 2800 to 3100 feet above sea level. This basin is not a natural drainage basin *per se*, but it does form a hydrologic entity. To the west and north, it is bounded by the St. Mary and Oldman Rivers. On the east, the boundary is a series of irrigation reservoirs, canals and drains. The southern and southeastern boundary coincides closely with the Lethbridge Moraine which is a surface drainage divide.

This basin is readily accessible by Alberta paved highways 3, 4, and 5 plus an excellent network of gravelled roads. Few spots are more than ½ mile from an all weather road. Two branches of the Canadian Pacific Railway serve the area, and the city of Lethbridge is also served by Air Canada and Lethbridge Air Service. The climate is classed as semi-arid, and as such, is extremely variable. Although average precipitation decreases from 17 inches to 14 inches per year from west to east, it has varied between 6 and 26 inches. Temperatures range from extremes of - 40° F to + 100° F. The growing season is about 144 days. Only one percent of the days are calm, and winds are strong in all seasons except summer. Soils are classed as "Brown" and "Dark Brown", and support a short grass prairie vegetation in their native state. Under irrigation, however, sugar beets and many vegetable crops are grown which could not be raised otherwise. For example, over half the frozen vegetables processed in Canada are produced at Lethbridge. A large portion of Canada's sugar beets are also grown in this area.

PURPOSE OF STUDY

In the past, the Canada Department of Agriculture has studied irrigation efficiency and other crop-related irrigation subjects. The St. Mary and Milk Rivers Development meters irrigation water. Other isolated studies have been conducted. This is the first time that an integrated program has been initiated in Canada to study all aspects of the hydrologic cycle in an irrigated basin. During the International Hydrologic Decade, all water entering and leaving the basin will be instrumented and measured.

It is the first time that such a comprehensive study has been undertaken in a glaciated area, and the only comprehensive irrigation study ever undertaken in Canada. Very few irrgiation projects have been built in glaciated areas outside Canada, whereas virtually all the 1,500,000 irrigated acres in Canada are in glacial and glaciolacustrine deposits.

Much Hydrologic data from American and Middle East irrigation studies have little application in Canada. It is therefore, expected that the results of this study will be of great value within Canada and other northern areas where irrigation is being or will be practised. The complexity and variety of investigations in this study require the co-operation and co-ordination of many scientists from several government agencies. The agencies involved are:

FEDERAL GOVERNMENT

1. Department of Agriculture, Lethbridge Research Station - supplies some of the material and labour for shallow groundwater installations.
2. Department of Energy, Mines and Resources - install gauges and measures discharge of streams within the basin.
3. Department of Transport - provides instrumentation for all meteorological parameters: precipitation, evaporation, solar radiation, temperature, wind velocity.
4. Prairie Farm Rehabilitation Administration - has supplied information on water delivery in certain areas.

PROVINCIAL GOVERNMENT

Alberta Department of Agriculture - Water Resources Division

1. Agrohydrology Branch - studies of soil moisture and water use by plants, irrigation water budget research.
2. Design and Construction Branch - construction of weirs for stream metering purposes.
3. Hydrology Branch - advisory capacity on various hydrologic parameters.
4. Soils, Geology and Groundwater Branch - establishes shallow water table wells, shallow and deep piezometer nests, and deep groundwater installations.

Research Council of Alberta - has done geologic and groundwater studies near Lethbridge; provides financial assistance for drilling.

St. Mary and Milk Rivers Development - measures and delivers water to the irrigation district.

HISTORY OF AREA

The first scientific studies conducted in this area were by the Palliser expedition, sent by the British Government in 1860 to evaluate agricultural potential of the area. It lies within the "Palliser triangle" where Captain Palliser could foresee no significant settlement because of the arid climate.

The region changed from an economy based on the fur trade to ranching in the 1870's. About 1890, homesteading began and much land was broken into small holdings within a few years.

Two events of significance occurred about this time. The first was the discovery and development of coal at Coal Banks, now Lethbridge. The Northwest Coal and Navigation Company built railways into the area in order to market their coal. As was government practice at the time, large tracts of land were granted as a subsidy to the railway for thus helping to develop the area. A subsidiary, the Alberta Railway and Irrigation Company, was formed in 1883 to irrigate this land so it could be sold at a profit. Its interests were taken over by the Canadian Pacific Railway in 1912. In 1946, the irrigation works were turned over to a crown corporation called St. Mary and Milk Rivers Development.

The second event of importance was immigration of Mormon settlers to Alberta from Utah and Idaho. These people had been irrigating for over forty years in the United States and were familiar with the problems and techniques of irrigation.

When the Alberta Railway and Irrigation Co. canal was built from Kimball to the Lethbridge-Coaldale area, these settlers provided the labor and equipment for its construction. They were paid partly in cash and partly in irrigable land. Construction was begun in 1899 and much of the system was in operation in 1902. This was not the first attempt at irrigation in Canada, but it was far more successful than earlier projects near Calgary. In 1951, a new reservoir on the St. Mary River was completed. This shortened the main canal and permitted considerable expansion and improvement of irrigation projects in the area.

The Irrigation Study Basin was conceived as a research project in the spring of 1965. Although several agencies had previously conducted studies of various subjects in this basin, it became obvious that an overall program, covering all aspects of water use was needed. Leadership was provided by Mr. L.D.M. Sadler, Supervisor of Soils and Drainage, Colonization Branch, Department of Agriculture, Lethbridge. It was realized that a program of this magnitude was too vast for any individual or any single organization to conduct. Consequently, other groups were approached who indicated their interest and willingness to participate.

A research program was organized during the summer and interested participants outlined their fields of interest and the estent to which they could contribute financially.

Approval was secured in the fall of 1965 for this to be accepted as an International Hydrologic Decade project. It's federal I.H.D. code is IWB-EB-14 and provincial code is ALTA 71.

The Irrigation Sub-Committee, made up of all participants in the study, meet annually to report progress and discuss current problems. Their meeting of July 27, 1966 reported the following installations in operation:

5 metering stations to measure surface water outflow

10 shallow and deep piezometer nests

¼ of anticipated meteorological instrumentation, including

1 evaporation pan

2 automatic precipitation gauges

2 atmometers

Although the P.F.R.A. is not an active participant, it supplied water measurements from several gauging stations along the Taber canal.

In 1967, the Colonization Branch was incorporated into the Water Resources Division, Alberta Dept. of Agriculture. Senior personnel of the Colonization Branch moved from Lethbridge to Edmonton, including Mr. Sadler, project co-ordinator.

At this time, a hydrogeologist, Mr. Grant Nielsen, was hired to administer technical aspects of the study.

The 1967 annual meeting of the Irrigation Sub-committee was held in Lethbridge on July 5. Problems resulting from an unusual six foot snow fall in May were discussed, such as resultant runoff destroying one metering station. The following items were reported to the committee:

> Most of the meteorological network is now complete. Deep groundwater instrumentation has begun and will continue through 1968. Efforts to measure all surface runoff are being expanded to some of the smaller coulees. It was decided to publish an annual report, this being the first one. An intensified study of the Readymade area will be started, in order to gain greater detail in a limited area.

REPORTS OF CO-OPERATING AGENCIES

Each of the following agencies has prepared a separate report on its own work and finding.

ALBERTA DEPARTMENT OF AGRICULTURE; WATER RESOURCES DIVISION

a. Agrohydrology Branch, - Jon Kelly

Introduction

The role of the Agrohydrology Branch in this I.H.D. study is the correlation of climatological data with crop use of water in relation to the hydrologic cycle to determine the water requirements of the study basin.

It was necessary to collect data on crop acreages, irrigation use, irrigation efficiencies, precipitation, and evaporation and the consumptive use of water by crops.

Daily readings are taken and records collected during the growing season (May 18th to September 27th for 1967). Climatological data is reported separately to the Department of Transport and in this report in only in summary form.

The initial soil moisture reserve is measured by taking soil samples from representative areas at the beginning of the season and measuring their moisture content.

Instrumentation

The twenty-six established instrumentation sites were planned so as to obtain a sufficiently complete coverage of the study basin to provide accurate data for evaluating the water requirements for Agriculture in the study basin.

TABLE 1

Sites serviced by
Agrohydrology Branch
Water Resources Division
Alberta Department of Agriculture

(see Fig. 2)

Site	Location	Equipment	Data Recorded
1	SW-14-9-19-4	a) Tower anemometer and anemograph.	a) Wind mileage and direction.
		b) Fisher-Porter precipitation gauge.	b) Continuous precipitation amount and intensity.
		c) Class "A" evaporation pan: 1) pan 2) max-min thermometers (water) 3) max-min thermometers (air) 4) standard rain gauge	c) 1 Daily evaporation 2 Daily max-min air temperature 3 Daily max-min water temperature. 4 Total daily rainfall 5 Total daily wind mileage

Site	Location	Equipment	Data Recorded
		5) cup counter anemometer d) Hygrothermograph.	d) Continuous temperature, continuous relative humidity.
2	N.E.19-18-19-4	a) Fisher-Porter precipitation gauge. b) Standard rain gauge.	a) Continuous precipitation amount and intensity. b) Total daily rainfall
3	N.E. 19-8-20-4	a) Fischer-Porter precipitation gauge. b) Standard rain gauge	a) Continuous precipitation amount and intensity. b) Total daily rainfall.
4	S.E. 22-9-20-4	Class "A" evaporation pan: 1) pan 2) max-min thermometers (water) 3) max-min thermometers (air) 4) standard rain gauge 5) cup counter anemometer	1) Daily evaporation. 2) Daily max-min water temperature. 3) Daily max-min air temperature. 4) Total daily rainfall 5) Total daily wind mileage
5	S.E. 16-9-21-4	Standard rain gauge	Total daily rainfall.
6	N.E. 18-9-20-4	Standard rain gauge	Total daily rainfall.
7	S.E. 29-9-19-4	Standard rain gauge	Total daily rainfall.
8	N.E. 11-10-19-4	Standard rain gauge	Total daily rainfall.
9	S.W. 6-9-18-4	Standard rain gauge	Total daily rainfall.
10	N.W. 17-8-13-4	Standard rain gauge	Total daily rainfall.
11	N.E. 26-8-19-4	Standard rain gauge	Total daily rainfall.
12	N.W. 10-8-19-4	Standard rain gauge	Total daily rainfall.
13	S.W. 3-9-19-4	Standard rain gauge	Total daily rainfall.
14	N.E. 31-8-19-4	Standard rain gauge	Total daily rainfall.
15	S.W. 7-8-19-4	Standard rain gauge	Total daily rainfall.
16	S.W. 2-9-20-4	Standard rain gauge	Total daily rainfall.
17	S.E. 5-9-20-4	Standard rain gauge	Total daily rainfall.

Site	Location	Equipment	Data Recorded
18	N.E. 32-7-20-4	Standard rain gauge	Total daily rainfall
19	N.W. 36-7-21-4	Standard rain gauge	Total daily rainfall
20	S.E. 12-10-21-4	Standard rain gauge	Total daily rainfall
21	N.E. 3-10-20-4	Standard rain gauge	Total daily rainfall
22	N.E. 13-10-19-4	Standard rain gauge	Total daily rainfall
23	S.W. 10-10-18-4	Standard rain gauge	Total daily rainfall
24	N.W. 34-9-21-4	Standard rain gauge	Total daily rainfall
25	S.W. 20-10-19-4	Standard rain gauge	Total daily rainfall
26	N.E. 9-8-21-4	Class "A" evaporation pan: 1) pan 2) max-min thermometers (water) 3) max-min thermometers (air) 4) standard rain gauge 5) cup counter anemometer	 1) Daily evaporation 2) Daily max-min water temperature 3) Daily max-min air temperature 4) total Daily rainfall 5) Total daily wind mileage.

The above mentioned equipment is supplied by the Canada Department of Transport, Meteorology Branch.

Land Utilization

The study area which includes the irrigation areas known as the Lethbridge - Coaldale distribution system, the Cameron Ranch extension, and the Readymade extension totals 247,200 acres. Approximately 4,608 acres of this is devoted to hard surfaced highways, railways, and urban areas. Another 2,363 acres of land is under water in the forms of lakes, reservoirs, canals, dugouts and ponds, etc. Non-productive crops such as trees, reeds, etc. absorb an additional 3,050 acres, leaving 237,185 acres for agricultural use.

Crop acreages (Table 2) were determined with the help of grain elevators, canning factories, and the sugar factory. Accurate information was available on only 190,988 acres. The figures for the remaining acreage was obtained by extrapolation on a ratio basis. The probable error in this table is ± 4% for any crop.

The non-arable acreage was calculated from aerial photographs, rights-of-way plans, etc. This includes the city of Lethbridge, town of Coaldale, hamlet of Hardieville, hard surfaced highways, railroad bed, airport runways, etc.

The area in non-productive crops (phreatophytes) was estimated from observance of aerial photographs and by field inspections and has a probable error of less than 20%.

The amount of water required for optimum crop growth was 292,192 or 234,086 acre feet more than the safe moisture reserve at the start of the season. Precipitation and irrigation water used was not sufficient to make up for the deficit. The deficit represents a deficiency in crop growth and a reduction in yield over the 1966 growing season which had a lower water requirement due to much higher precipitation and less evaporation.

Soil Moisture

The growing season began approximately two weeks later than normal for this area because of some five feet of snow from two major snowstorms late in April. This unusually large amount of precipitation left the moisture reserve in the soil at field capacity.

The soil within the study basin was divided into three main categories; light, medium, and heavy soils. (See Figure 1).

TABLE 2

LAND UTILIZATION	ACREAGE	MOISTURE REQUIREMENT	
		INCHES	ACRE FEET
Wheat	76,138	18.21	115,730
Oats	8,158	18.21	12,400
Barley	35,597	18.21	54,107
Rye	494	24.17	993
Flax	988	24.17	1,986
Misc. Grain	160	18.21	243
Mustard	291	24.17	585
Sugar Beets	6,631	21.94	12,135
Potatoes	202	21.74	366
Corn	150	19.58	246
Peas	1,985	17.43	2,878
Beans	190	15.40	243
Misc. Vegetables	117	15.40	150
Forage Crops	21,778	25.81	46,823
Pasture	22,892	20.60	39,608
Phreatophytes	3,050 *	24.00	3,700
Summerfallow	61,408	4.00 **	20,449 **
Water Surface	2,363	40.05 **	7,886 **
Non-Arable Land	4,608	-	-
	247,200		320,528

* 1200 acres of phreatophytes growing along the Oldman River are most likely drawing their moisture from this source and therefore are not included in the Moisture Requirement total.

** These figures are for evaporation only and do not include consumptive use for crops.

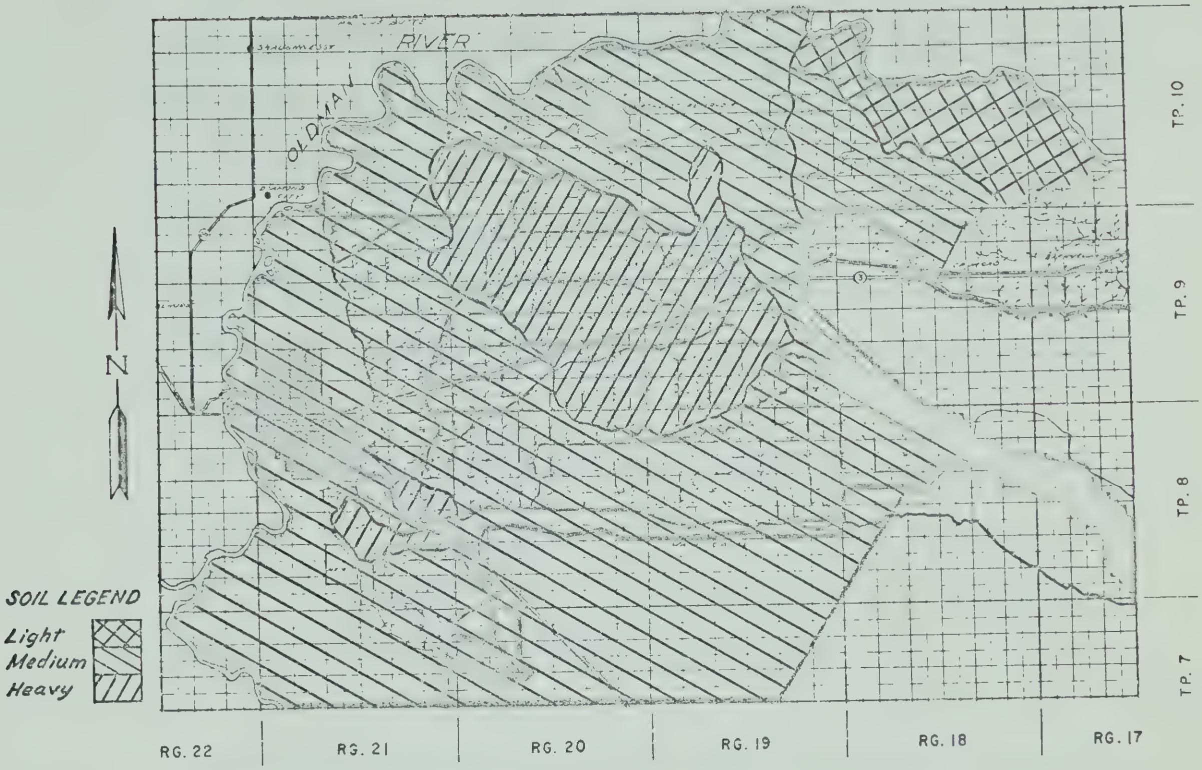

FIGURE I

THREE BASIC SOIL TEXTURES WITHIN STUDY AREA

About 5.7% of the area is a light soil, 78.2% a medium soil and 16.1% a heavy soil. For a light soil, the total available water for crop use in a four foot root zone is 5.1 inches from which 3.0 inches may be safely depleted without significant loss in yield. For a medium soil, the total available water is approximately 7.5 inches from which 3.8 inches may be so depleted. For a heavy soil the figures are 10.0 inches and 4.6 inches respectively. These figures are approximate and are taken to be a characteristic average for the three basic soil divisions in this basin. They are correct to within 10%.

Based on these figures, the total available water stored in the root zone of the study basin at the beginning of the season was 171, 900 acre feet. The amount of safe moisture reserve for the basin at the start of the season was 78, 104 acre feet.

Precipitation

The precipitation for the growing season averaged from twenty-six recording stations was 5.06 inches. This is almost 5.00 inches less than the normal precipitation based on the long time average recorded at the Lethbridge airport. The May and June precipitation was near normal while the months of July, August and September were much below normal. (See Table 3).

The variation in rainfall ranged from 4.30 inches at the easterly edge of the study area to 6.10 inches to the west, (see rainfall patterns). With an average of 5.06 inches of rain over the study area for the period of May 18th to September 27th, the total precipitation for the growing season amounted to 103,842 acre feet.

The amount of precipitation that could be contributed to runoff this season was estimated to be very slight as the soil moisture at periods of rainfall was down sufficiently to allow almost complete penetration of the soil.

Evaporation

Evaporation data was taken from three "Class A" pans located at sites 1,4 and 26 of figure 2. Accurate correction factors to get open surface evaporation were not possible for 1967. Water temperatures were not known except for Henderson Lake. Humidity was only known for site 1. The correction factor should be approximately 75% but will vary. In the absence of reliable correction factors, a value of 75% is used for all open water surfaces. The error is assumed to be within 10%.

The average total evaporation from the three pans was 40.05 inches of wa water. The highest daily evaporation was 0.55 inches on June 28th. The highest monthly evaporation was for the month of July which averaged 0.36 inches per day.

The total water surface area within the study basin was estimated to be 2,363 acres. This area consists of canals, laterals, lakes, ponding areas, reservoirs and dugouts. Based on 30.04 inches of open water evaporation the water lost from these surfaces amounts to 5,913 acre feet.

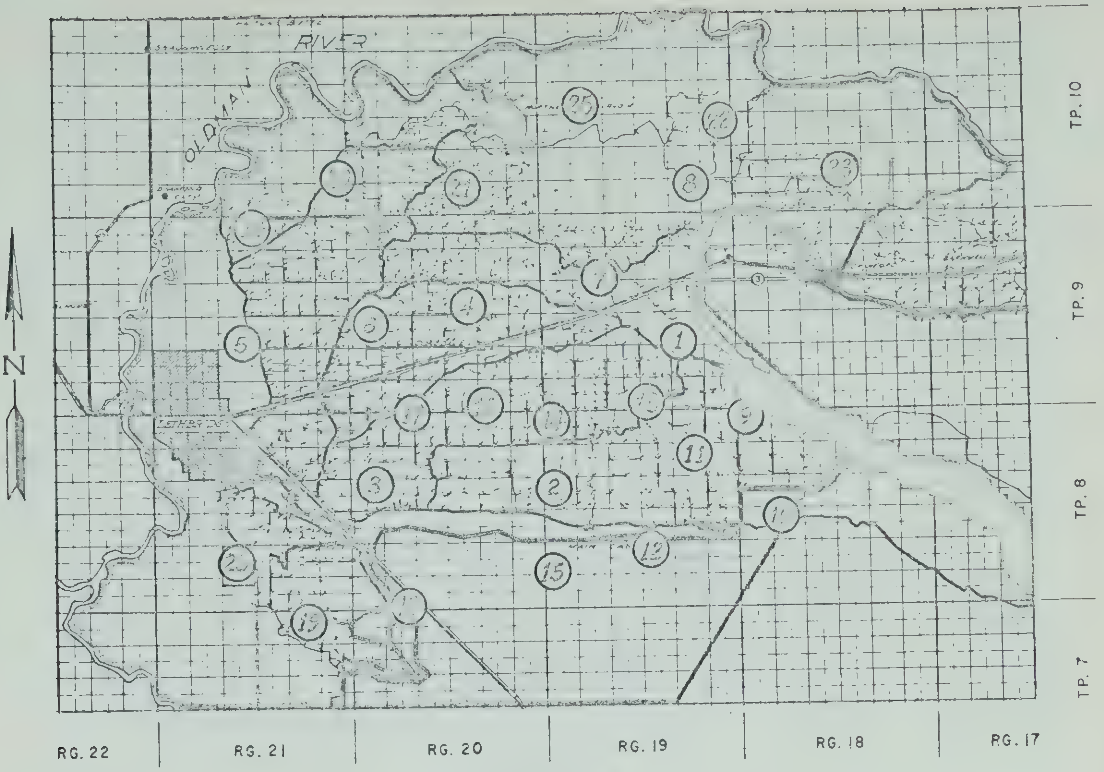

FIGURE 2

MONTHLY PRECIPITATION FOR 1967 GROWING SEASON
(MAY 18 TO SEPTEMBER 27)

Site	May	June	July	August	September
1	1.02	3.13	0.26	0.54	0.27
2	1.07	3.19	0.09	0.67	0.27
3	1.33	2.31	0.16	0.91	0.73
4	1.05	3.03	0.05	0.55	0.32
5	1.50	2.46	0.04	0.73	0.50
6	1.56	3.13	0.07	0.63	0.34
7	1.04	2.76	0.32	0.66	0.33
8	0.97	3.00	0.42	0.55	0.29
9	0.98	2.23	0.41	0.48	0.35
10	0.95	2.46	0.23	0.46	0.38
11	0.95	2.40	0.08	0.51	0.34
12	1.06	2.85	0.21	0.47	0.33
13	0.99	2.55	0.09	0.57	0.28
14	0.98	2.83	0.10	0.75	0.31
15	-	-	0.01	0.89	0.45
16	1.20	2.57	0.08	0.65	0.31
17	1.38	2.85	0.11	0.77	0.94
18	1.24	2.40	0.15	1.03	0.48
19	1.29	2.25	0.22	0.86	0.50
20	-	-	0.07	0.48	0.42
21	-	-	0.11	0.67	0.32
22	-	-	0.36	0.49	0.27
23	-	-	0.25	0.72	0.29
24	-	-	0.09	0.38	0.46
25	-	-	0.35	0.55	0.46
26	1.27	2.82	0.34	0.80	0.51
Average	1.15	2.69	0.18	0.64	0.40
Normal	2.09	3.20	1.69	1.64	1.36

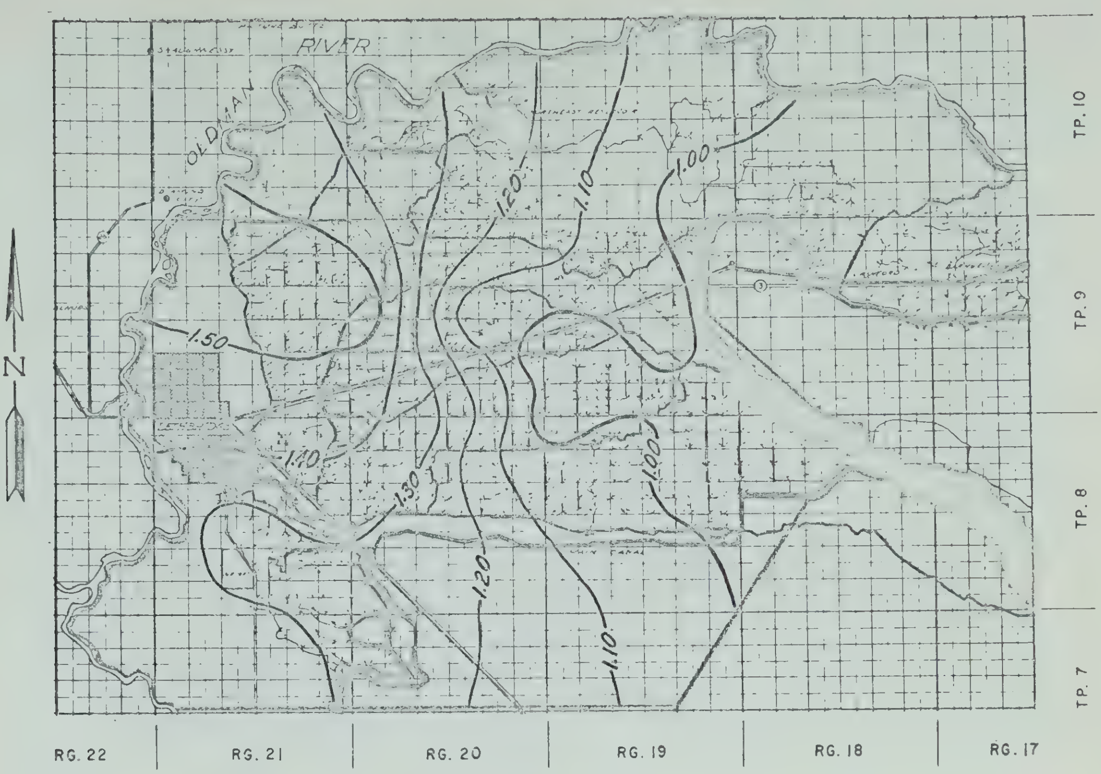

FIGURE 3

Precipitation-May 18 - 31 (inches)

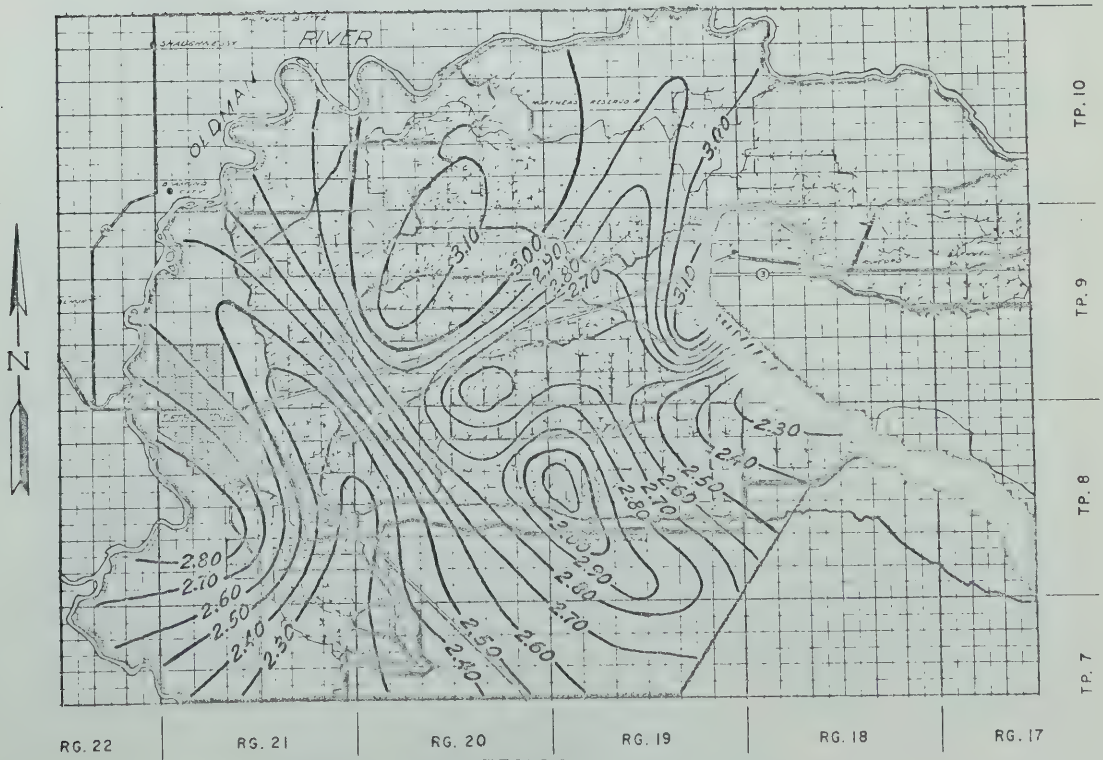

FIGURE 4

Precipitation-June (inches)

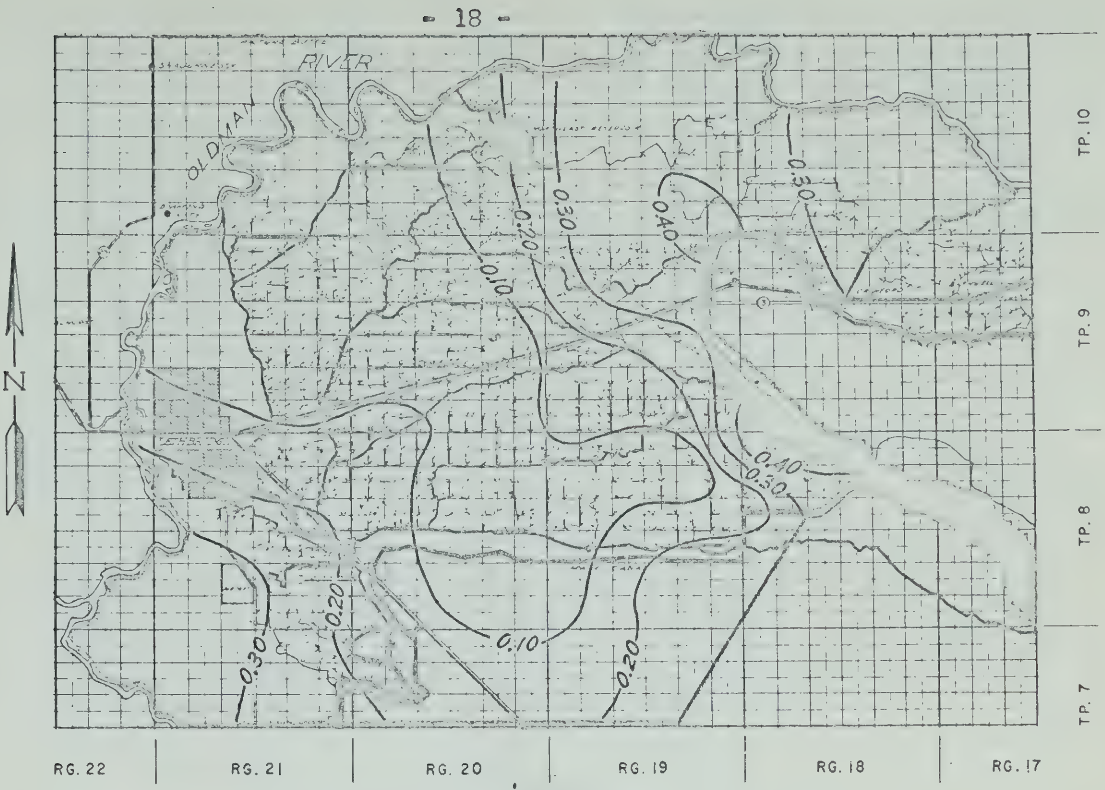

FIGURE 5

Precipitation-July (inches)

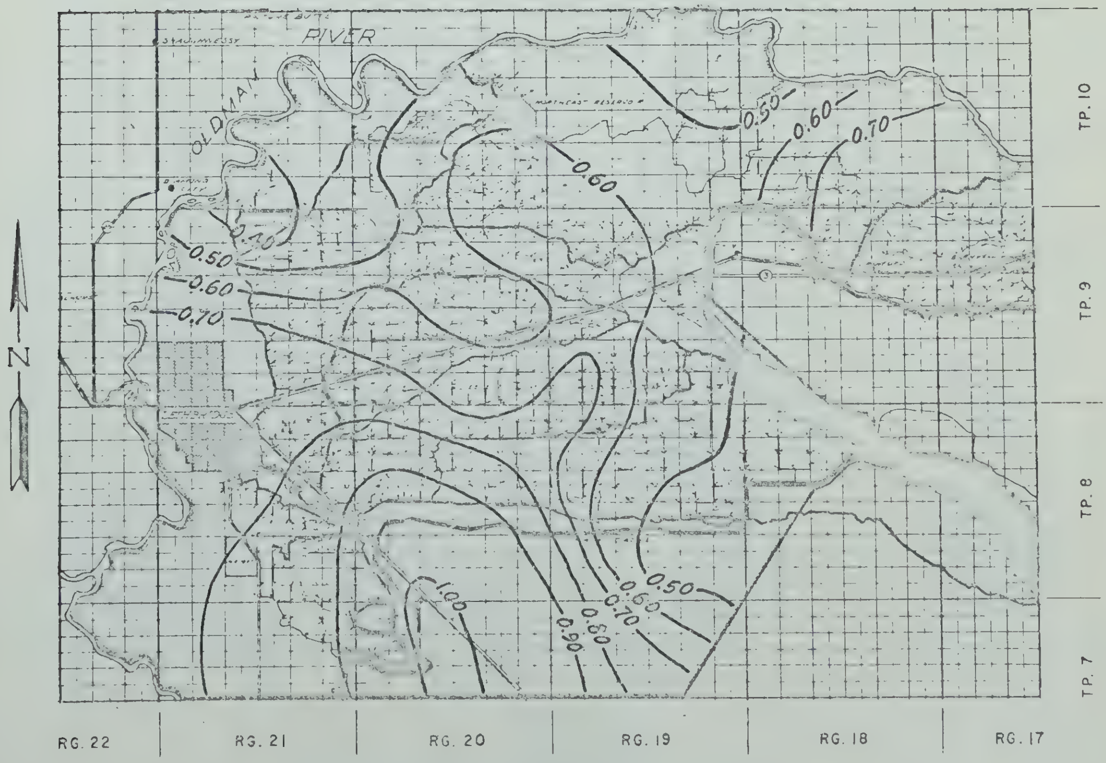

FIGURE 6

Precipitation-August (inches)

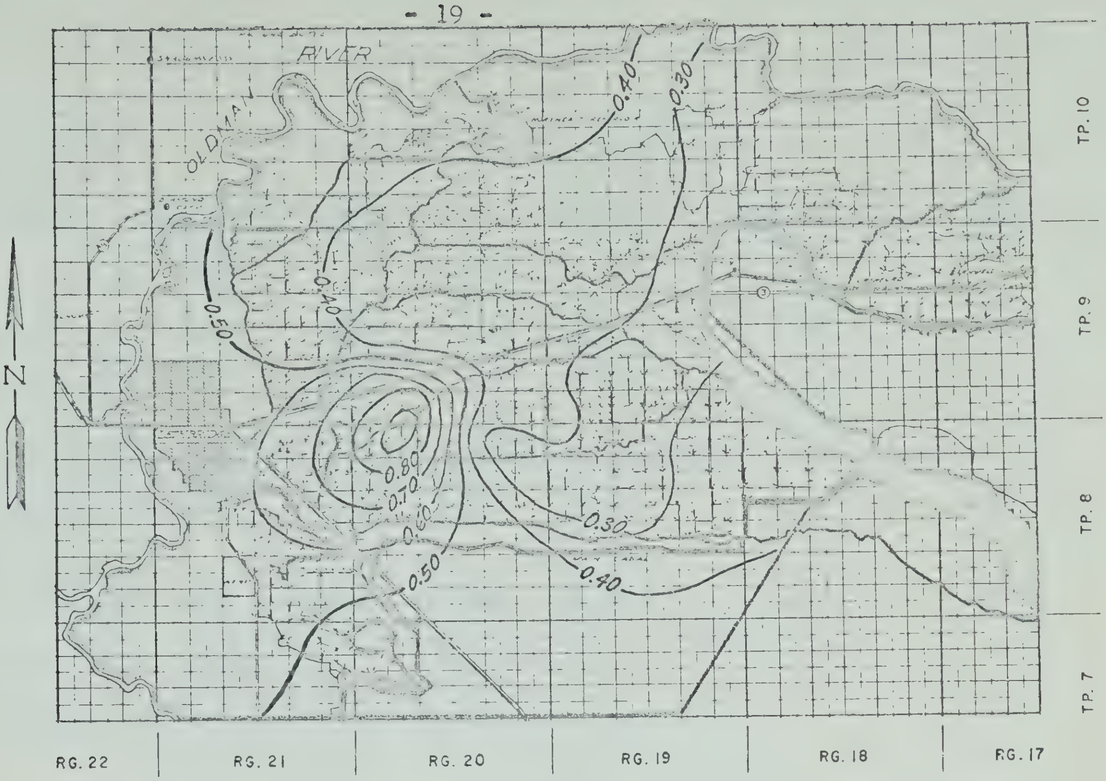

FIGURE 7

Precipitation-September (inches)

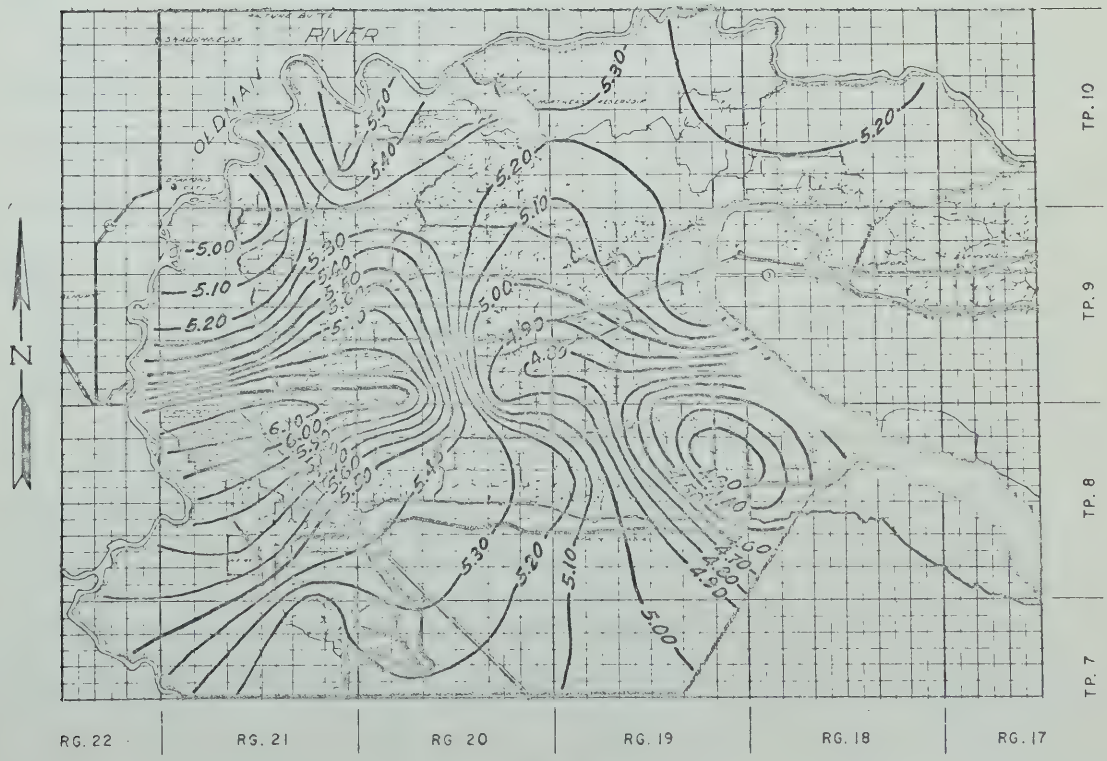

FIGURE 8

Total Precipitation (inches)

TABLE 4 1967 EVAPORATION LOSSES (inches)

Site	May 18-31	June	July	August	September 1-27	Total
1	3.45	7.79	10.75	9.00	8.47	
4	3.38	8.35	11.71	8.65	7.50	
26	-	-	-	9.82	8.56	
Average	3.41	8.07	11.23	9.16	8.18	40.05
Corrected Values	2.56	6.05	8.42	6.87	6.13	30.04

Open Water Surface - 2,363 acres

Water Lost to Evaporation - 5,913 acre feet

Irrigation

The total amount of irrigation water delivered during the growing season as recorded by the St. Mary and Milk Rivers Development was 59, 112 acre feet. With irrigation sprinklers as well as various gravity methods of applying water being used in the study area, it is difficult to determine an overall efficiency value. From evaluation test conducted in the area using several irrigation methods, it was estimated that the average farm system is about 50% efficient. This being the case, the amount of irrigation water that was useful for crop growth would be 29,556 acre feet.

The non-useful 50% represents deep percolation into the water table and runoff which collects in ditches and ponds to be evaporated or returned to the water table through percolation. A certain amount of this represents repletion of water evaporated from water surfaces. This was impossible to estimate with any accuracy and hence was ignored.

The irrigation water applied to different crops is tabulated in the water balance (Table 5). Irrigated and non-irrigated land are lumped together and hence it appears that irrigation failed to provide adequate water for all but summerfallow. In fact, the water deficit is distributed non-uniformly over the basin and in dryland conditions was more critical than it appears in the table.

Water Balance

Figures for daily root zone water loss due to evaporation from the ground and transpiration through plants were determined by evaporation from "Class A" evaporation pans. These determinations were based on data provided by the Research Station at Lethbridge and are averaged data valid over the range of 100 millibars (field capacity) to 500 millibars of moisture tension on a Sandy Loam soil. The latter represents the minimum moisture level that will support optimum yield. It is this figure which establishes the limit of safe depletion and hence the amount of water that may be depleted from a field without significant loss of yield. These figures were used for other soils and for dryland as well as irrigated areas. For dryland farmers the moisture level fell well below this point and lower evaporation figures should be used. This data, however, is unavailable.

Since 66% of the agricultural land is not irrigated and falls into this category, there is a significant error in stating that 318,554 acre feet of water entered the atmosphere from the study basin root zone. (see Water Balance - Table 5). However, the water balance is concerned with water needed for optimum plant growth which requires that soil moisture be maintained at or above the limit of safe depletion. The Research Station data is therefore used to determine the water taken from the soil by

TABLE 5

WATER BALANCE - 1967 GROWING SEASON

Crop Types and Land Use	Cereal, Oilseed	Sugar Beets	Vegetable, Specialty	Pasture, Forage	Phreatophytes, Trees, etc.	Summerfallow, Stubble	Under Water	Non - Arable	
	ACRE FEET OF MOISTURE								TOTALS
Moisture Requirement	186,044	12,135	3,882	86,431	3,700	20,449	5,913	-	318,554
* Safe Moisture Reserve (pre-season)	39,663	2,414	862	14,547	620	19,998	-	-	78,104
Precipitation	51,166	2,785	1,111	18,763	1,297	20,265	992	1,935	98,314
Irrigation Water Used	8,340	8,710	985	9,825	-	1,578	118	-	29,556
Total Moisture Available									205,974
Surplus Water	-	1,774	-	-	-	21,392	-	1,935	25,101
Water Deficit	86,875	-	924	43,296	1,783	-	4,803	-	137,681
Net Deficit									112,580
Crop Deficit	86,875		924	43,296	1,783				132,878
Irrigation Water Lost (runoff and deep percolation)	8,340	8,710	985	9,825	-	1,578	118	-	29,556

* That water in the root zone which can be removed without significant loss of yield. The water remaining after that is a basic water requirement and must be maintained to sustain a high yield. This was determined at the Lethbridge Research Station by comparing yield with minimum moisture levels for several crops.

evapotranspiration had minimum moisture conditions been met, which is then properly considered the moisture requirement for the irrigation basin.

Three sources of water were available to crops during the growing season, the initial safe moisture reserve, precipitation during the season, and irrigation. The total amount available from the three sources was 205, 974 acre feet, hence there was a net deficit of 112,580 acre feet for the irrigation basin.

Climatological Summary

The climatological data concerned with in this phase of the program are evaporation, temperature, relative humidity, wind and precipitation. Figures 9, 10, 11 and 12 contain daily data for humidity and average temperatures, wind mileage, land evaporation respectively.

With a high rate of evaporation and below normal precipitation the moisture requirement for crop use was quite high during the latter part of the growing season. The total evaporation for the 1967 growing season wa slightly higher than the previous season. The higher mean temperatures for 1967 would tend to indicate a much higher rate of evaporation than the previous year, however, the wind mileage was below the normal for this area, and hence it was only slightly higher.

Proposals For 1968

In 1968 a more intensified study is planned for the Readymade extension of the irrigation distribution system. This is to be treated as a mini-basin within the study basin. Water will be measured at strategic points throughout the canal distribution system to determine water use, inflow, outflow etc.

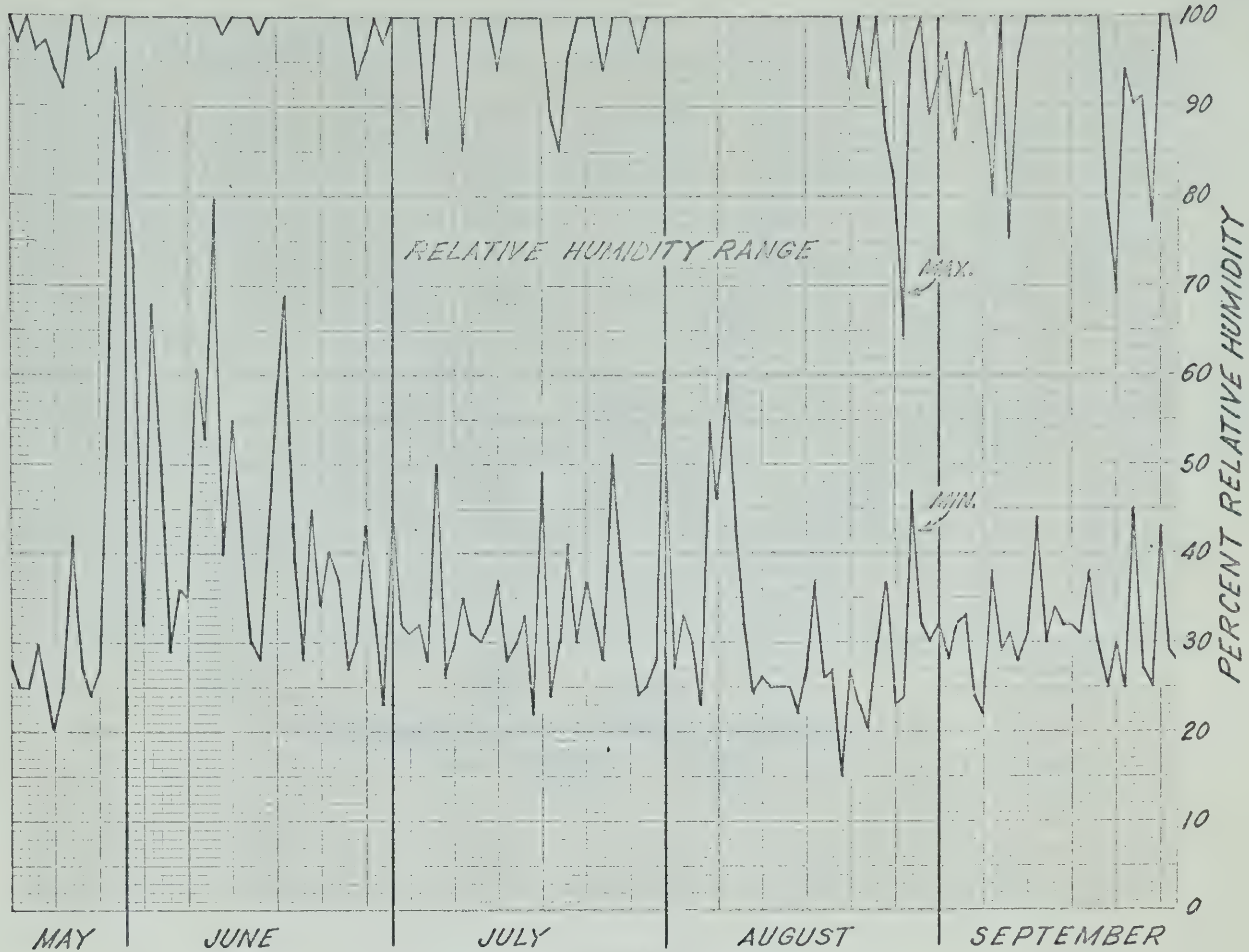

FIGURE 9

DAILY MAX.-MIN. LEVELS OF RELATIVE HUMIDITY
1967 GROWING SEASON

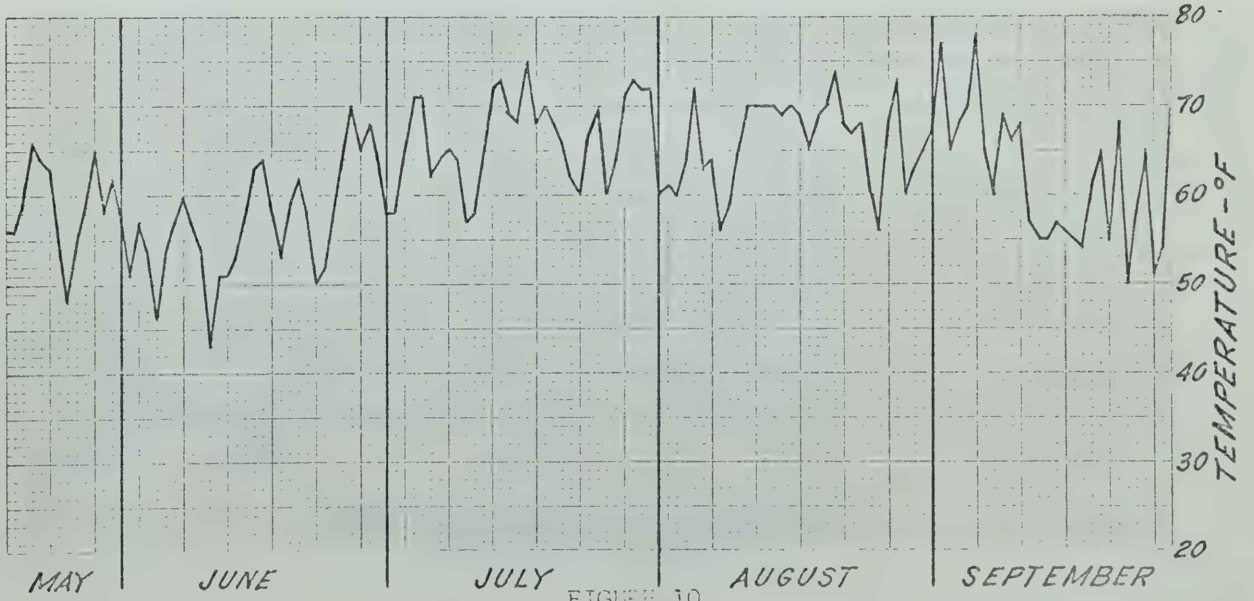

FIGURE 10

AVERAGE MEAN DAILY TEMPERATURE
1967 GROWING SEASON

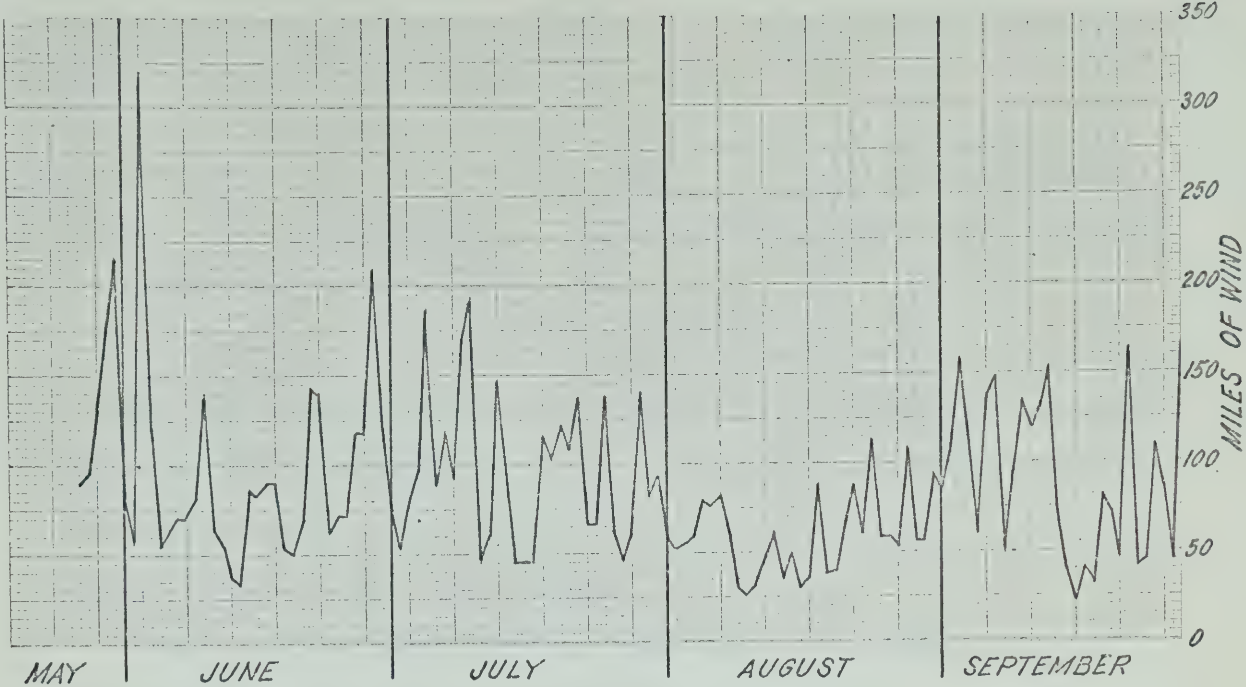

FIGURE 11

AVERAGE DAILY WIND MILEAGE

1967 GROWING SEASON

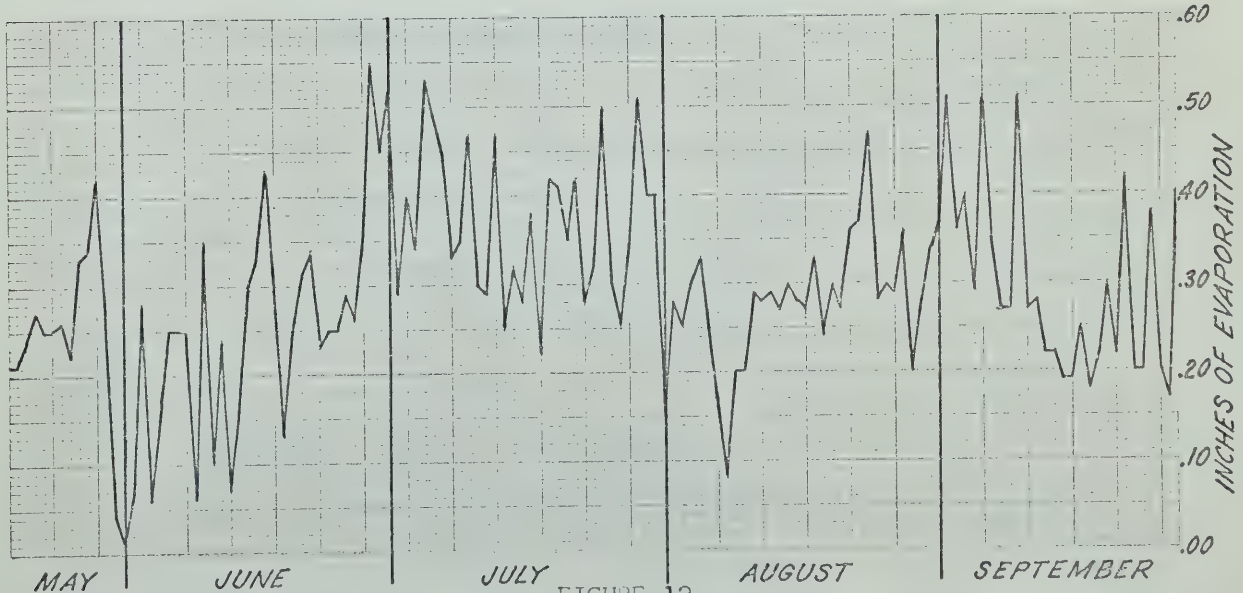

FIGURE 12

AVERAGE DAILY EVAPORATION

1967 GROWING SEASON

Instrumentation will involve the installation of water measuring devices and one additional rain gauge. This will provide a more accurate picture of the utilization of irrigation water.

The 1968 study will attempt to separate the irrigated and non-irrigated acreage into separate water balance studies for a more accurate picture of water needs. In connection with this, a study plot will be established to determine consumptive use of crops under dryland conditions. This will provide a more accurate water balance.

There will be installed in the study basin, an instrument to measure solar radiation. This will permit the correlation of crop yield with energy balance and may provide a more accurate means of measuring consumptive use of water by crops than is presently used.

Additional instrumentation will be installed to determine accurate correction factors for canal and lake evaporation.

b. Design and Construction Branch - R.L. Francis

This branch provides the labour and materials for installation of metering stations within the basin. The sites for such installations are chosen in co-operation with Mr. A.S. Qureshi, Water Survey of Canada, Canada Dept. of Energy, Mines and Resources. Most of this branch's work is now completed, except for some small stations to be placed along the margins of the Readymade sub-basin in 1968.

c. Hydrology Branch - R.K. Deeprose

The Hydrology Branch is offering the benefit of its training and experience for overall planning and interpretation in a consultant role . Information gained from this study will in turn be useful in province-wide water-shed research being conducted by the Hydrology Branch.

d. Soils, Geology and Groundwater Branch - G.L. Nielsen and L.J. McCracken

This branch has a two-fold interest in the study basin. The first responsibility is that of directing and co-ordinating the efforts of all the other participants. The initial impetus for organizing the study was provided three years ago by Mr. L.D.M. Sadler, Branch Head, who has been project co-ordinator since that time.

In addition this branch is responsible for measurement of all groundwater flow in and out of the basin. Inasmuch as groundwater flow is controlled or affected by the geology to a large extent, it is also necessary to map the geology in detail. Much of this work has been done by Dr. Warren Geiger, Research Council of Alberta. His bedrock topography has been published and another report is in preparation.

Work done so far has been largely exploratory, although a number of piezometer nests have been installed. Installations now in operation may be tabulated as follows:

18	deep groundwater piezometer nests, 80 to 260 feet deep, with up to 3 piezometers per nest.
164	shallow non-instrumented water table wells, 15 feet deep. These measure infiltration of irrigation water.
20	differential piezometer nests, each with piezometers at 10, 16, 33, 52 and 82 feet.
2	recording groundwater observation wells.

The average depth to water (in feet) in the shallow water table wells is summarized as follows, according to sub-basins as shown in Figure 13.

Table 6 Average Depth To Water In Shallow Water Table Wells

	1962	1963	1964	1965	1966	1967
Cameron	-	-	-	-	8.9	9.1
Chin	-	-	-	8.1	8.3	6.7
Coaldale	-	-	-	-	-	6.6
Eight Mile Lake	-	-	-	5.4	5.5	5.9
Hyssop	-	-	-	-	6.95	6.05
Maclaine	-	-	-	4.25	4.65	4.7
Readymade	-	-	-	-	4.0	4.9
Six Mile Coulee	6.25	6.75	5.8	5.1	5.6	5.2
Verbaan	-	-	-	6.25	6.55	6.7

Since the total number of water table wells has been increased each year, caution must be exercised in trying to interpret trends of rise or fall in the above data.

An attempt was made to establish the nature of the deep groundwater flow system in a profile north-south through Coaldale, but measurements so far are inadequate to do so. Some of the deep groundwater piezometers have required over a year to attain equilibrium, and interpretation from those which have not done so would be meaningless.

During 1967, some 40 holes were drilled, most of them by a contract driller, for exploratory purposes. The driller and a soils technician described samples from each holes, and each was logged electrically upon completion. During the summer, the branch acquired a side-hole sampler, a truck-mounted machine to take undisturbed samples from the walls of a hole after its completion. Most of the holes were also sampled in this way.

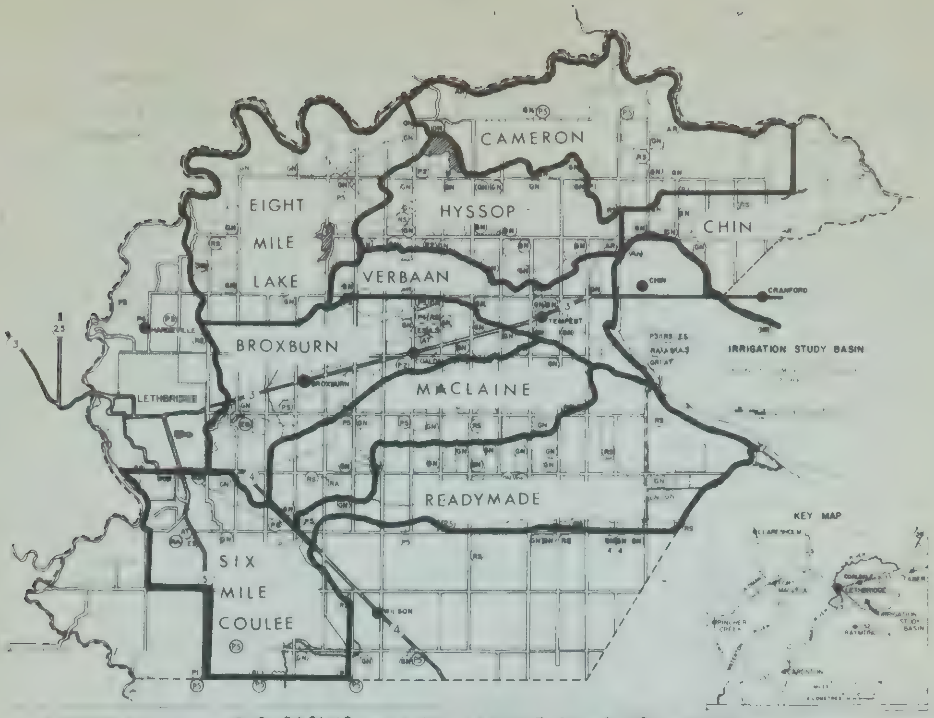

FIGURE 13 SUB-BASINS WITHIN IRRIGATION STUDY BASIN

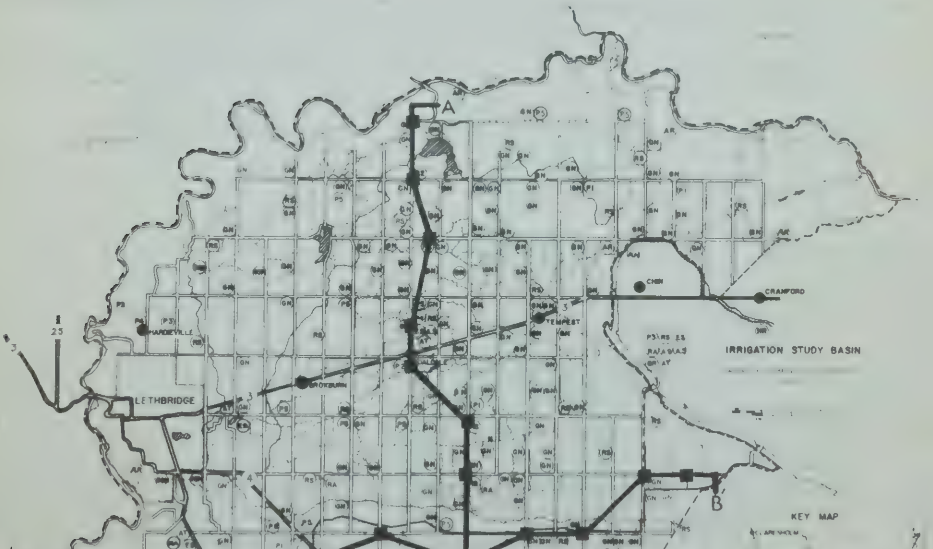

FIGURE 14 LOCATION MAP OF GEOLOGIC CROSS-SECTION

Results of this program have been evaluated, and it has been possible to make electric log correlations of the various horizons across the basin. These are shown in Figures 14, 15, and 16.

Bedrock in the basin consists of non-marine soft sandstone, siltstone, shale, and coal seams of the Belly River Group. In the vicinity of the city of Lethbridge, these sediments are overlain by the Bearpaw Formation, which is mainly soft dark grey marine shale. All bedrock is Upper Cretaceous in age and dips westerly at about 50 feet per mile.

Quaternary geology is somewhat complex. Immediately above the bedrock surface is a discontinuous series of sands and gravels, termed Saskatchewan Sands and Gravels. These deposits are probably Pliocene to Pleistocene and are preglacial alluvial deposits. Their distribution and thickness are shown in Figure 17. The greater amount of data now available has permitted more detail in outlining of preglacial river channels. Glacial and inter-glacial deposits are summarized as follows:

Upper Till - from a few to over 100 feet thick, has a variable color, somewhat bouldery, sand and gravel at top and base, but rarely within it.

Lenzie Silts - five to over 100 feet thick, with rapid variations of thickness, buff stratified silt and silty sand, may be reworked into a zone rather than a distinct horizon, forms an interglacial lacustrine deposit.

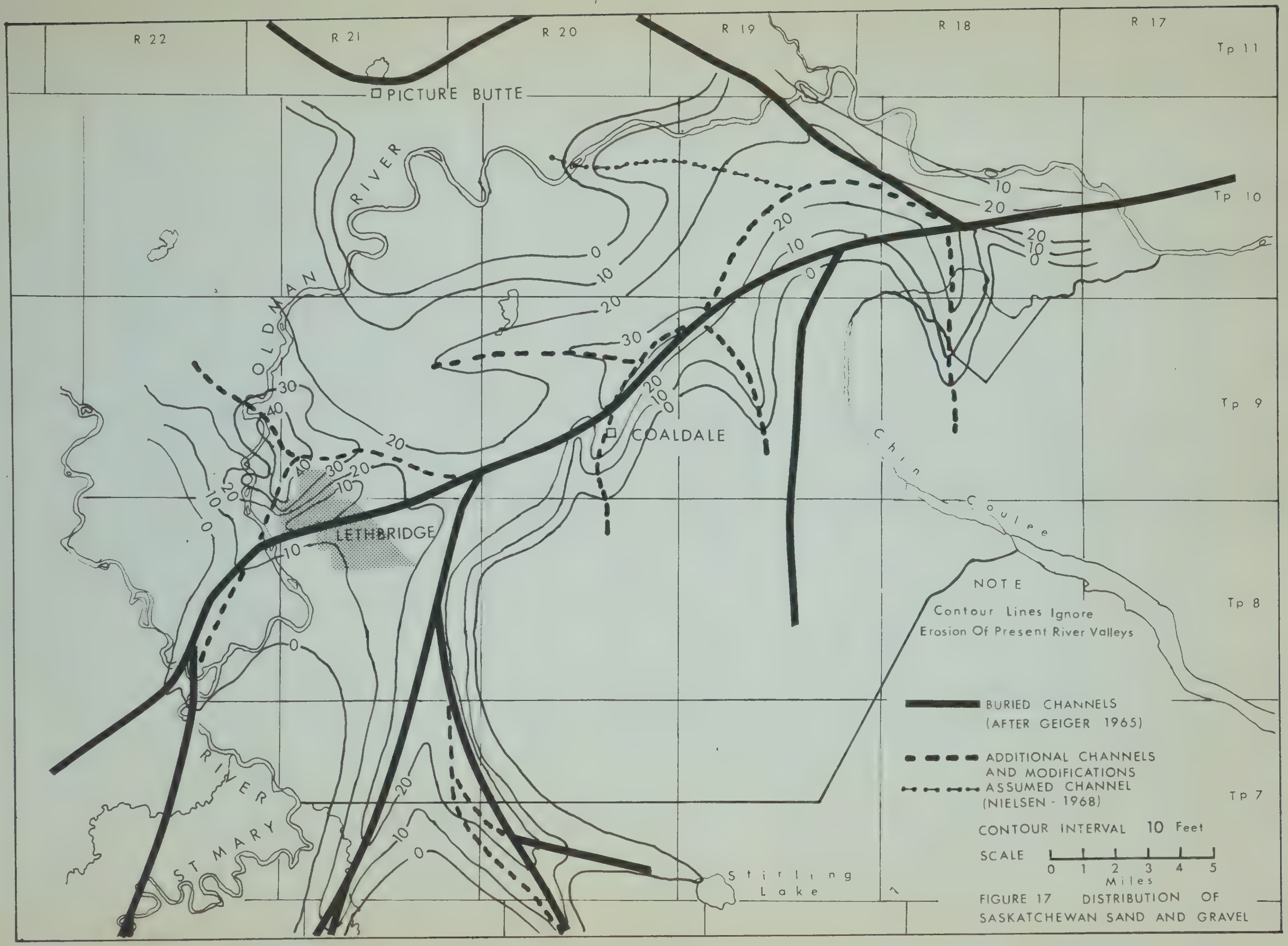

FIGURE 17 DISTRIBUTION OF SASKATCHEWAN SAND AND GRAVEL

Lower Till -	20 to over 90 feet thick, fills in irregularities of bedrock surface, sand and gravel layers at top and base and within till, contains Bedrock Masses horizon, more strongly indurated than Upper Till and may be vertically jointed at top.
Basal Till -	one to twelve feet thick, lies directly on bedrock or Saskatchewan Gravels, very hard and columnar, low pebble content except at top; calcareous, gypsiferous, dark grey - brown.

A second lacustrine deposit, formed after the final glacial retreat, lies at the land surface in much of the basin. It consists of brown silt and clay and reaches a maximum thickness of forty feet. This deposit has not been given a formal name.

Because of the lack of adequate data so far, it is too soon to make meaningful calculations of groundwater discharge or recharge in the basin. In 1968, two profiles of piezometer nests will be installed from the Lethbridge moraine north to Oldman River. One east-west line will be installed. These will yield adequate information on the nature of the groundwater flow system.

Hydraulic conductivity tests, both in the field and laboratory, will be conducted where possible. Thus it will be possible to make proper calculations of groundwater volume leaving or entering the basin, once the piezometers reach equilibrium.

The line of piezometer nests to be installed in the Readymade sub-basin will be read and maintained by this branch. One automatic recording observation well will be installed in this area. These will be drilled under contract to the Research Council of Alberta.

CANADA DEPT. OF AGRICULTURE; LETHBRIDGE RESEARCH STATION

prepared by Egon Rapp.

The main contribution of the Research Station, Canada Dept. of Agriculture, Lethbridge, in the Irrigation Study Basin project to date has been in the study of the shallow groundwater phase. Readings on these installations are taken on a 2 month basis with water samples taken every other reading. This involves, on the average, 5 man-days of a technician's time for each reading.

At the present time, the shallow groundwater network consists of 164 observation wells installed to a depth of 15 feet and on an irregular spacing. The wells are usually located in relation to canals and drains or legal survey boundaries. This observation well network is actually an extension of an earlier network established by the Soils, Geology and Groundwater Branch of the Alberta Water Resources Division. In addition, 85 piezometers in 20 batteries and consisting of 1 to 5 piezometers per battery located at selected sites are read concurrently with the observation wells.

Work planned for 1968 involves installation of additional observation wells and piezometers, mainly to improve the present network density. The Canada Department of Agriculture, Research Branch is contributing materials and manpower for this work. As in the past, instrumentation will be the joint respons of the Research Station and the Soils, Geology and Groundwater Branch.

The installation reading and water sampling schedule for 1968 will be reviewed with the other co-operating agencies involved. Processing and analysis of data will be discussed in order to improve the value if this information in the over-all hydrologic study of the basin.

CANADA DEPT. OF ENERGY, MINES AND RESOURCES, prepared by A.S. Qureshi

Introduction

Water Survey of Canada (in co-operation with the S.M.R.D. Irrigation District Office) is primarily in charge of collecting and publishing the hydrometric data in the basin. To this end, the hydrometric instrumentation installed and operated by this organization, is comprised of six automatic recording type water level gauges in addition to one manual type water level gauge, all operated during the open water season i.e. generally from March to October. The instrumentation supplemented by the streamgauging stations operated in the area by the S.M.R.D. Irrigation District Office, is designed primarily to measure the surface water supply to and the resulting return flow from the Basin. A brief description of the instrumentation at each site is given below.

A Stevens A-35 negator-spring water level recording gauge is installed on each of the following streams:

1. Nolan Coulee
2. Bountiful Coulee
3. Six Mile Coulee
4. Lateral Ten Spillway
5. Cameron Lateral
6. Taber Irrigation District Canal

The gauges on streams No. 1 to 4 measure the Basin surface return flow spilled into the Oldman River while No. 5 (Cameron Lateral) measures the surface return flow discharges into the Chin Reservoir. A major part of this return flow has been observed to be irrigation excess water.

Stable hydrometric controls have been achieved through artifical means at stations No. 1 to 5. The controls at the "Nolan" and the "Bountiful" Coulees consist of a precast conrete weir with horizontal crested opening installed roughly twenty feet downstream of the gauging section. In case of the "Six Mile Coulee" the concrete control provided about fifteen feet downstream of the gauging section also acts as a flow measuring apron. In addition, a steel cableway has also been constructed above the control section at the "Six Mile Coulee", in order to measure high flows. Stable control conditions at the "Lateral Ten Spillway" and the "Cameron Lateral" have been achieved by locating the gauging sections, respectively, thirty-three and forty-five feet upstream of the existing drop structures (wooden flumes). Stream No. 6 above i.e., "Taber Irrigation District Canal" has a natural control.

In addition to above recording gauges, a manual type gauge is provided at the headgates of the Bountiful Coulee in order to measure the Chin Reservoir outflow to Bountiful Coulee. The latter gauge consists of two staff rods, one fixed upstream and the other downstream of the headgates. Both of these staff rods are observed every second day along with the gate opening.

Apart from above permanent instrumentation, a program of miscellaneous flow observations is being conducted at ten reasonably sized outflow coulees, two main storm sewers in the Main Basin and one Main Outflow Coulee in the "Readymade Sub-Basin".

The data being collected may be classified into following two broad categories:

Observed Data

1. Continuous gauge heights (i.e. stage) record at the automatic recording stations and instantaneous daily gauge heights at the manual type stations.
2. Discharge measurements with sufficient frequency to define a stage discharge relationship i.e., rating curve.

Processed Data

- Daily mean gauge heights
- Daily mean discharge
- Monthly mean discharge
- Total monthly flow volume (acre-feet); and
- Other related streamflow information like maximum and minimum daily mean discharge during a month.

Efforts are being made to achieve stage-discharge relationship at the above stations. So far such satisfactory relationships have been achieved for the case of the following streams:

- Six Mile Coulee
- Lateral Ten Spillway
- Bountiful Coulee
- Cameron Lateral
- Taber Irrigation District Canal

with poor ratings at:

- Nolan Coulee
- Chin Reservoir Outflow to Bountiful Coulee

Based on the actual data, the total irrigation water diverted to the Basin during 1966-67 season, through the "Taber Irrigation District Canal" and the "Bountiful Coulee", is estimated to be 10,200 acre-feet, while the surface return flow from the Basin, spilled into the Oldman River and the Chin Reservoir by the various gauged coulees, is estimated to be 21,600 acre-feet.

The above irrigation diversion to the Basin and the return flow from the Basin are only a portion, the remainder being gauged by the S.M.R.D. Irrigation District Office by means of their own hydrometric network in the area.

Accuracy of Data

The error in flow data observations is estimated to be in the order of ±2% on a mean monthly basis, for stations at which an adequate concrete control is installed. For stations with natural control the error may be of the order of ±5% in the mean monthly flows.

Future Plans

The hydrometric instrumentation presently in use at the Main Basin has been considered adequate for measuring surface water.

Intensive hydrometric instrumentation of the Readymade Sub-basin, which may consist of three or four automatic recording and several manual gauges is expected to take place early next season. The hydrometric data thus collected are expected to be used in determining the minimum number of factors which should be known in order to compute a partial water budget in a similar irrigation area, in addition to the utilization of

this data in irrigational studies and research by the other co-operating agencies.

DEPARTMENT OF TRANSPORT: METEOROLOGICAL BRANCH, - by Avard Mann

The planning for a network of meteorological instruments for the Lethbridge-Taber area Irrigation Study Basin began in 1965 and the first sites were developed in the summer of 1966. Because of the large area included in this study, it was necessary to plan the network which would be both costly to install and difficult to maintain.

For the purpose of this study the definition of the aerial distribution of rainfall was considered most significant and to meet this requirement a gauge separation of 5 miles was chosen and 26 sites in the area were identified. Twenty-two were in operation in 1966 and the remaining four the following year. In arriving at this gauge density, reference was made to WMO publications and to the work done by D.M. Hirshfield of the U.S. Agriculture Research Service. Hirshfield's method is based on the rainfall regime of an area and in this case would indicate that a gauge spacing of 2 miles would provide a correlation factor between gauges of r=0.9.

Because of the large area of their study it has not been possible to make the initial network of this density. The cost of installing and maintaining such a network are prohibitive. The approach which has been made so far is realistic and will yield data which will meet the initial requirements of this study at least.

To assess precipitation intensity four sites were selected on a southwest-northeast line across the area. A ratio of one recording gauge to ten standard gauges is the recommended density for this type of instrumentation. The operation of the Fischer-Porter recording gauges has so far been unsatisfactory for the purposes of this study and of the 16 months service of 3 gauges only 6 months are complete and useable. It is planned next season to install an MSC type rain recorder in conjunction with one of these sites.

Evaporation is measured at four sites - 3 using Class A pans and one a 4 foot sunken pan and the same 4 sites are instrumented for temperature and humidity.

The weather for 1967 was characterized by a near normal winter season which was succeeded by extremely high spring snow fall and a very dry summer and fall. The normal snow fall for March, April and May is 91.1 inches whereas 106.7 inches were measured in these three months in 1967. The normal rainfall for July through October 1s 5.12 inches but only 1.96 inches was recorded in this period in 1967. The year closed with December recording much above normal snowfall - 24.8 inches compared with a long-term normal of 7.5 inches.

RESEARCH COUNCIL OF ALBERTA: GROUNDWATER DIVISION, by

Don H. Lennox

Since 1963 evaluation of the geology and groundwater resources of the Lethbridge area has been an important Research Council project. Field work was completed in 1966 and a manuscript describing observations and conclusions is now being prepared. A first draft (which will be made available to the project technical co-ordinator) is expected in the spring of 1968.

The data collected and compiled, as well as the completed and published study, will provide valuable background information for the Irrigation Study Basin investigation.

The groundwater phase of the Irrigation Study Basin investigation has been allocated to the Water Resources Division of the Department of Agriculture but the Research Council has acted as a consultant to Water Resources and will continue to act in this capacity as occasion requires. The Research Council has volunteered to supply water-level recorders for continuous recording of water-level fluctuations in observation wells at selected sites. One such recorder was installed at the instrumented site to the west of Chin Lakes in Sec. 14, Tp.9, R.19. This site was not satisfactory, so the recorder was moved to McNally School, SE-13-8-21-W4. Two recorder installations are planned for 1968, one of these will probably be in the Readymade area which has been selected for an intensive and detailed hydrologic study.

The Research Council has agreed to pay the costs of a drilling and instrumentation program to be carried out in the Readymade area in 1968 and to be supervised by the Water Resources Division. It will lead to the installation of a series of piezometer nests along the north-south line formed by the east boundaries of Secs. 19,30, and 31, Tp.8, R.18 and Sec. 6, Tp.9, R.18.

Present plans call for at least 4 nests with at least 2 piezometers per nest. Piezometer depths will be decided after consideration of the known geology but generally one piezometer in each nest will be located a short distance below the bedrock surface.

The objectives of the piezometer installations are the delineation of the pattern of natural groundwater movement, the determination of the effects of irrigation activities, and the estimation of the amount of return flow that follows the groundwater route.

ST. MARY AND MILK RIVERS DEVELOPMENT, by - J.H. Graham

Records of discharge at all S.M.R.D. gauging stations are available at the Lethbridge office to anybody who wishes to use them.

The total quantity of irrigation water applied in the basin in 1967 and its distribution by crop are discussed in the report of the Agrohydrology Branch, Water Resources Division, Alberta Department of Agriculture.

Runoff metered by the S.M.R.D., including excess irrigation water and natural runoff was 34,985 acre-feet.

SUMMARY AND CONCLUSIONS

The goal of this study is to establish the water budget for an irrigated area, and to measure or calculate each of the parameters invloved. These parameters are expressed in the hydrologic equation:

$$P + I = E_t + Q + Sm + Sg + Gw + Ss$$

in which P = precipitation
I = irrigation
E_t = evapotranspiration (consumptive use)
Q = surface runoff
Sm = Change in soil moisture storage
Sg = change in groundwater storage
Gw = groundwater discharge
S_s = change in surface water storage

The following parameters have been successfully measured for 1967.

P = 17:21" at airport $P+I$ = 20.09"

I = 2.88"

Q = 2.75"

An effort must be made by the participants to measure or calculate the remaining parameters if this project is to be successful in future years.

Instrumentation for the entire basin is about 85% complete. The groundwater network is the project needing most additional work at the present time. It is anticipated that all instrumentation will be virtually complete at the end of 1968. Efforts will then be concentrated on accumulation and interpretation of data for the balance of the International Hydrological Decade.

Instrumentation in operation at the time of writing is summarized as follows:

Table 7 - Instrumentation Now in Use in Irrigation Study Basin

5	recording metering stations with concrete headwall
1	recording metering station with natural bed
1	non-recording metering station natural bed
164	shallow water table observation wells, 15 feet deep
1	recording deep groundwater observation well
1	recording shallow water-table well
18	deep groundwater piezometer nests, 80 to 260 feet deep, with up to 3 piezometers per nest.

20	differential piezometer nests, each having piezometers at 10, 16, 33, 52 and 82 feet
26	standard rain gauges
4	Fischer - Porter precipitation gauges
2	Anemovane anemometers mounted on 30 foot (9meter) tower, with recording anemograph in shelter.
3	cup counter anemometers (about 0.5 meters high)
1	hygrothermograph
8	sets Dept. of Transport standard maximum - minimum thermometers, (4 for atmosphere, 4 in evaporation pans)
3	class A evaporation pans
1	sunken evaporation pan

In preparation of this report, all the authors have used certain words rather frequently. There is a significance to these words: co-ordinate, co-operate, discuss, participate, etc. Such an ambitious undertaking would be totally impossible if one individual or one organization were to attempt it alone.

The diversity of disciplines, and the amount of training and experience necessary are totally beyond the scope of any individual or organization. The success of this program has resulted from the willingness of many people in many fields of endeavor to work together toward a common goal.

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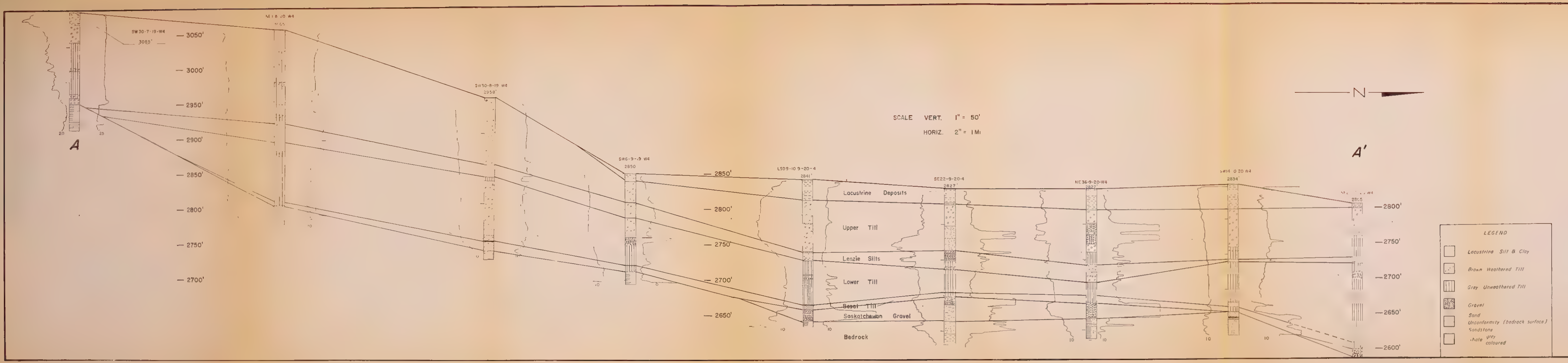
Mr. Glen Steed (on leave of absence)
Agrohydrology Branch
Water Resources Division
Box 907,
Lethbridge, Alberta.

Mr. R.B. Wells
P.F.R.A.
Lethbridge, Alberta.



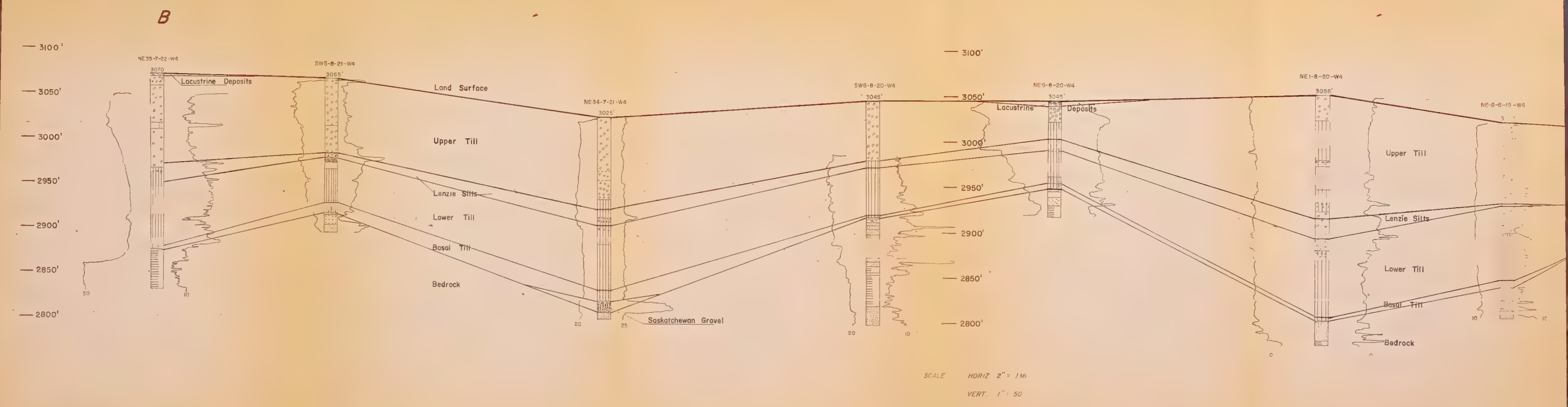
GOVERNMENT OF ALBERTA

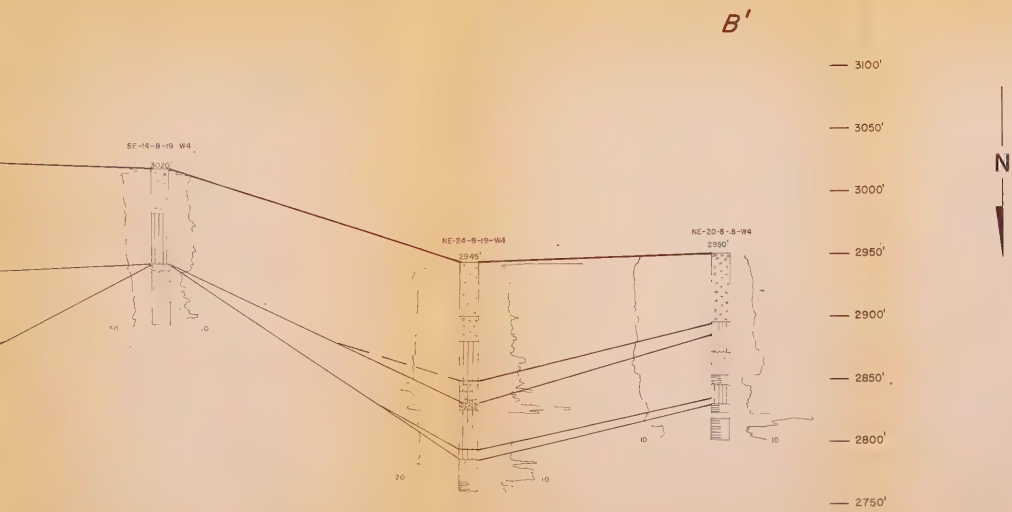
SOILS GEOLOGY & GROUNDWATER BRANCH

FIGURE 15

SOUTH-NORTH CROSS-SECTION A—A'

L.D.W. Sadler


B
3100'
3050'
3000'
2950'
2900'
2850'
2800'
NE35-7-22-W4
3070
Lacustrine Deposits
SW5-8-21-W4
3065'
Land Surface
NE34-7-21-W4
3025'
Upper Till
Lenzie Silts
Lower Till
Basal Till
Bedrock
Saskatchewan Gravel
50
10
20
25
SW8-8-20-W4
3045'
3100'
3050'
3000'
2950'
2900'
2850'
2800'
20
10
NE9-8-20-W4
3045'
Lacustrine
Deposits
NE1-8-20-W4
3056'
NE-8-8-19-W4
Upper Till
Lenzie Silts
Lower Till
Basal Till
Bedrock
10
10
SCALE HORIZ 2" = 1 Mi
VERT. 1" = 50



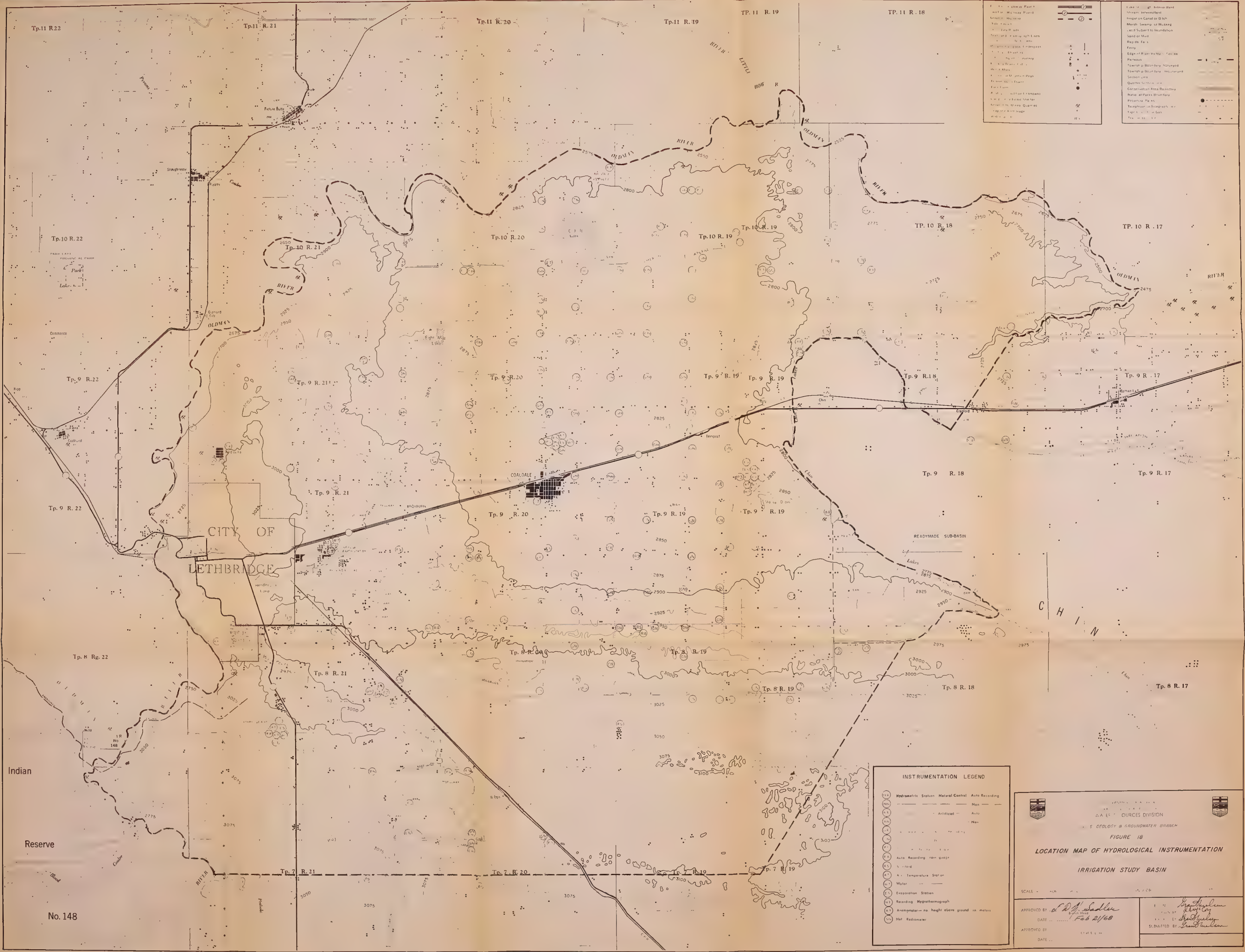
GOVERNMENT OF ALBERTA
WATER RESOURCES

SOILS GEOLOGY & GROUNDWATER BRANCH

FIGURE 16

EAST — WEST CROSS-SECTION B — B'

As Shown
Feb/68



WATER RESOURCES DIVISION

GEOLOGY & GROUNDWATER BRANCH

FIGURE 18

LOCATION MAP OF HYDROLOGICAL INSTRUMENTATION

IRRIGATION STUDY BASIN

SCALE -

APPROVED BY L.D.G. Sadler
Branch Head
DATE ...... Feb 21/68

APPROVED BY
DATE ..

SUBMITTED BY Grant Nielsen